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The Transponder System: A New Method of Precise Catheter Placement in the Right Atrium Under Echocardiographic Guidance

JOEL S. LANDZBERG, MD,* JAY O. FRANKLIN, MD, JONATHAN J. LANGBERG, MD, JOHN M. HERRE, MD, FACC, MELVIN M. SCHEINMAN, MD, FACC, NELSON B. SCHILLER, MD, FACC

San Francisco, California

The ability to localize catheters within the heart has gained importance with the use of percutaneous catheter ablation and the transseptal approach for valvuloplasty. A prototype interactive transponder catheter system, specifically designed to mark the catheter tip for echocardiographic visualization, was used to place catheters at the tricuspid anulus and the fossa ovalis in anesthetized dogs. Catheter tip location was marked by lesions produced by radiofrequency energy delivered at the distal catheter electrode. At autopsy, the center of the radiofrequency-induced lesion was located 2.8 ± 0.7 mm from the edge of the lateral tricuspid anulus and 3.5 ± 3.1 mm from the center of the fossa ovalis. The transponder catheter system offers the ability to precisely position catheters in the right atrium under echocardiographic guidance.

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Catheter localization in the heart has gained importance with the use of catheter ablation for the treatment of arrhythmias and the transseptal approach for balloon valvuloplasty. Percutaneous catheter ablation has been used to interrupt posteroseptal accessory pathways in patients with the Wolff-Parkinson-White syndrome (1). Catheter techniques have been infrequently utilized for ablation of right free wall accessory pathways, in large part because of difficulty in assessing whether the catheter is close enough to the tricuspid anulus for successful ablation (2). With increased use of the transseptal approach for mitral and aortic (3) valvuloplasty, often in patients with distorted anatomic landmarks and by laboratories without substantial experience in the use of transseptal catheterization, the potential for an increase in complications exists.

Echocardiographic guidance of intracardiac catheter placement has been limited by inadequate identification of the catheter tip; each point where the catheter crosses the scanning plane can be misconstrued as the catheter tip (4). The recent development by Cikes and coworkers (4,5) of the transponder system allows visualization of cardiac anatomy by echocardiography and enables the physician to confidently determine catheter tip location. We used a prototype interactive transponder catheter system (Telectronics, Inc.), specifically designed to mark the catheter tip for echocardiographic visualization, to place catheters at the fossa ovalis and lateral tricuspid anulus. The aim was to determine whether we could enhance precision of catheter placement in the right atrium.

Methods

Transponder system (Fig. 1). A standard 6F tripolar electrode catheter with 5 mm interelectrode spacing was modified by substituting a piezoelectric crystal for the middle electrode. When stimulated by an ultrasound pulse, this piezoelectric crystal generates a small voltage that is detected by the transponder receiver. The receiver activates the pulse generator, producing an electronic "reply" in the form of a series of voltage pulses transmitted back down the catheter. These pulses cause the piezoelectric crystal to vibrate, generating an ultrasound signal that is visualized on the two-dimensional echocardiographic image as a marker in the position where the piezoelectric crystal is located. Maximal gain is used for initial localization of the catheter tip signal, and then the gain is minimized to allow increased precision.

From the Division of Cardiology of the Department of Medicine and the Cardiovascular Research Institute, University of California, San Francisco, California. This study was supported in part by a grant from Telectronics, Inc., Englewood, Colorado and Grant HL36291 from the National Institutes of Health, Bethesda, Maryland.

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*Present address and address for reprints: Joel S. Landzberg, MD, Department of Medicine, Cardiovascular Division, Brigham and Women's Hospital, 75 Francis Street, Boston, Massachusetts 02115.

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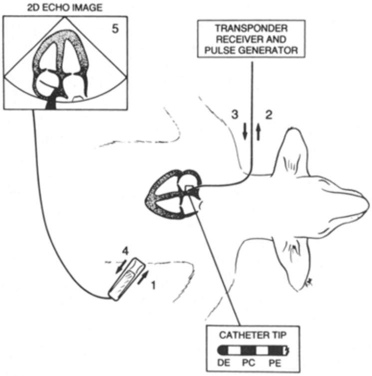


Figure 1. Schematic representation of transponder system with catheter in the right atrium of a dog: 1) The transducer generates an ultrasound pulse wave; 2) the piezoelectric crystal (PC) converts the ultrasound pulse wave to an electrical signal that is detected by the receiver; 3) the pulse generator sends a series of voltage pulses down the catheter causing the piezoelectric crystal to vibrate, generating an ultrasound response; 4) the transducer receives the reply; 5) the echocardiographic (ECHO) image displays a marker at the position of the true catheter tip. DE = distal electrode; PE = proximal electrode.

Experimental protocol. Fourteen adult mongrel dogs (18 to 27 kg) were sedated with fentanyl, anesthetized with sodium pentobarbital (10 to 30 mg/kg body weight), intubated and ventilated mechanically (Harvard respirator). The electrocardiogram (ECG) and blood pressure were monitored continuously (Electronics for Medicine VR 16). Echocardiograms were performed with a 5 MHz transducer (Ausonics MicroImager 1000). The dogs were imaged in the right lateral decubitus position at the point of maximal impulse.

To accurately mark the location of the catheter, a small endocardial lesion was created by applying radiofrequency current between the distal catheter electrode and a chest wall patch. The radiofrequency power source (Microvasive Bicap) produced a 550 kHz unmodulated output; the total delivered energy was 97 ± 88 joules.

Tricuspid anulus (Fig. 2). The transponder catheter was introduced through a sheath placed in the external jugular vein, advanced to the right atrium and then positioned near the lateral tricuspid anulus under biplane fluoroscopic guidance. With use of the transponder system, the catheter tip was then visualized in both the short-axis and apical four chamber views for three-dimensional localization (Fig. 2A and B). Adjustments were made under echocardiographic guidance until the catheter tip was as close as possible to the tricuspid anulus. Radiofrequency energy was then applied to mark the location of the catheter tip (Fig. 2C).

Fossa ovalis. To simulate placement of a transseptal needle, a transponder catheter was bonded to a Brockenbrough stylet, allowing enhanced catheter control for positioning at the fossa ovalis in nine dogs. This catheter was introduced by way of the femoral vein, advanced through the inferior vena cava to the right atrium and positioned at the presumed site of the interatrial septum under single plane posteroanterior fluoroscopic guidance. With use of the transponder system, the catheter tip was then visualized in both the short-axis and apical four chamber views. Adjustments were made under echocardiographic guidance until the catheter tip appeared to be in the fossa ovalis. Once optimal position was attained, radiofrequency energy was applied to mark the location of the catheter tip.

At autopsy, distances were measured along the endocardial surface, from the center of the radiofrequency-induced lesion to the corresponding anatomic target (tricuspid anulus or center of the fossa ovalis).

Studies conformed to the "Position of the American Heart Association on Research Animal Use."

Results

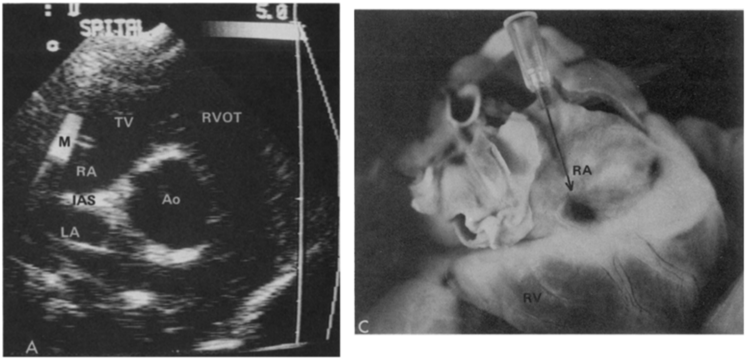
Echocardiographic localization of the transponder. In all 14 dogs, adequate short-axis and apical four chamber views were obtained to allow visualization of the right atrium and three-dimensional determination of catheter tip location. The short-axis view at the cardiac base delineates the interatrial septum, showing it to be to the right and posterior to the aortic root. The apical four chamber view also provided visualization of the interatrial septum and allowed the catheter tip to be placed against the midseptum. Angulating the scanning transducer anteriorly and posteriorly allowed confirmation of the catheter tip position relative to the aortic root. The lesions created by radiofrequency energy were 4.7 ± 1.5 mm in diameter (range 2.0 to 8.2).

Tricuspid anulus. The distance between the center of the radiofrequency-induced lesion and the edge of the tricuspid anulus was 2.8 ± 0.7 mm (Table 1).

Fossa ovalis. The fossa ovalis in dogs consists of a shallow depression (6) measuring approximately 9 mm in diameter. The distance between the center of the radiofrequency-induced lesion and the center of the fossa ovalis was 3.5 ± 3.1 mm (Table 1); accuracy improved with experience.

Discussion

Previous studies on echocardiographic visualization of catheters. The initial studies of echocardiographic visualization of intracardiac catheters were descriptive, discussing the appearance of balloon flotation catheters and pacemaker



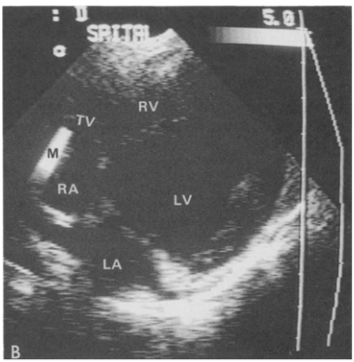


Figure 2. Echocardiographic visualization of the transponder catheter tip at the lateral tricuspid anulus in short-axis (A) and apical four chamber (B) views. The pathologic specimen (C) shows a radiofrequency-induced lesion below the pointer at the tricuspid anulus. Ao = aortic valve; IAS = interatrial septum; LA = left atrium; LV = left ventricle; M = marker at catheter tip; RA = right atrium; RV = right ventricle; RVOT = right ventricular outflow tract; TV = tricuspid valve.

catheters on M-mode echocardiograms (7,8). With improved resolution, statements could be made about catheter position. Gondi and Nanda (9) were able to detect pacemaker-induced myocardial perforation in five patients. Drinkovic (10) used subcostal echocardiography to determine pacing catheter position in 30 patients and was able to detect pacemaker perforation of the ventricular septum in 1 of them. Kronzon et al. (11) performed echocardiography on 13 patients undergoing fluoroscopically guided transseptal catheterization. Fluoroscopy was used to position the catheter at the fossa ovalis, and use of contrast echocardiography provided confirmation of the position of the catheter in the left atrium after puncture.

With further improvements in image quality, echocardiography was utilized to help guide catheter placement. It was employed to position catheters in pregnant women undergoing left ventriculography or aortography in an attempt to minimize fetal radiation exposure (12,13). In children, echocardiography was used to guide balloon atrial septostomy and to confirm adequacy of results (14,15). French et al. (16) used echocardiography to assist endomyocardial biopsy in seven children. However, they noted that lateral beam spread and reverberation artifacts limited the accuracy of catheter placement.

Role of the transponder in catheter placement. The development of the transponder system by Cikes and coworkers

JACC Vol. 12, No. 3
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Table 1. Distances From Center of Radiofrequency-Induced Lesions to Anatomic Targets

Dog No.	Distance From Fossa Ovalis (mm)	Distance From Tricuspid Anulus (mm)
1	—	3.0
2	—	3.0
3	—	2.5
4	—	2.5
5	—	2.3
6	8.0	2.5
7	9.0	3.2
8	3.5	2.8
9	0.8	5.0
10	3.5	2.0
11	1.4	2.8
12	0.5	2.5
13	3.2	2.0
14	1.2	3.0
Mean	3.5	2.8
SD	3.1	0.7

(4,5) has allowed the physician confident localization of the catheter tip while the cardiac anatomy is visualized with echocardiography. Placement of the piezoelectric crystal on the distal catheter allows it to interact in either a passive or an active mode with the transponder system. In the passive system the piezoelectric crystal acts solely as a receiver, detecting the signal from the ultrasound scanner. This mode requires specialized electronic circuitry within the ultrasound scanner to allow placement of a marker on the two-dimensional echocardiographic image at the position where the catheter tip is located. In the active mode, which we utilized, the piezoelectric crystal acts as both a receiver and a generator. It detects the ultrasound scanner signal, relays this information to the transponder system and then generates an ultrasound signal reply that is visualized on the echocardiographic image as an easily identifiable marker. The active system can be used with any ultrasound system, thus avoiding the scanner dependence and specially designed electronic circuitry required in the passive mode.

Using radiofrequency-induced lesions to provide anatomic confirmation of catheter position, we have demonstrated the ability to precisely position the transponder catheter in the right atrium under echocardiographic guidance in anesthetized dogs. In all dogs, lesions placed at the lateral tricuspid anulus were in areas where they would have provided optimal potential for success of catheter ablation of right free wall accessory pathways. All lesions placed at the fossa ovalis were located in positions where a Brockenbrough transseptal needle would have crossed the interatrial septum without puncturing either the aorta or the free wall of the right atrium.

Conclusions. The transponder system offers the potential ability to ablate right atrial free wall accessory pathways and improve the safety of transseptal catheterization. Further trials will be necessary to evaluate its utility in humans, as well as its potential to decrease both patient and operator exposure to ionizing radiation.

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